SPECIAL REPORT 94-29

CRREL

Effects of Seed Treatments on Germination

Deborah Diemand, Antonio J. Palazzo and Mohammad Sharif

September 1994

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Abstract

The goal of this study was to identify ways to stimulate the germination of seeds of various grasses and legumes of potential value in revegetation of army training grounds or similar damaged lands. Ten treatments (including a control) were used on ten species of plants. Four of the treatments used plant hormones (kinetin and gibberellic acid), and five were environmental, including cold exposure, hot water soaks and cold water soaks. Of these the gibberellic acid treatments yielded the most spectacular results, increasing the germination rate more than three times that of the control in some cases. The environmental treatments were relatively ineffective, although the hot water soaks and the cold exposure often suppressed germination somewhat. Microbial contamination was much reduced by the hot water soak, which may be beneficial in some circumstances.

For conversion of SI metric units to U.S./British customary units of measurement consult *Standard Practice for Use of the International System of Units (SI)*, ASTM Standard E380-89a, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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Special Report 94-29

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

Effects of Seed Treatments on Germination

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September 1994

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Prepared for
U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY

PREFACE

This report was prepared by Deborah Diemand, Physical Scientist, Applied Research Branch, Experimental Engineering Division; Antonio Palazzo, Research Agronomist, Geochemical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory; and Moham[illegible] Sharif, Agricultural Engineer, U.S. Army Construction Engineering Research Lab[illegible].

This study was conducted by stud[illegible] [illegible] Vermont Technical College under the guidance of CRREL researchers. The authors [illegible]ank [illegible]ynn Whalen, Instructor of Plant Propagation at Vermont Technical College, and the students of this course—Timothy W. Allen, David L. Batten, Jared H. Clawson, Brian F. English, Anthony J. Punt, Christine J. Warley—for their capable assistance.

Funding was provided by the U.S. Army Construction Engineering Research Laboratory, Champaign, Illinois.

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Effects of Seed Treatments on Germination

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INTRODUCTION

Army training lands require periodic plant re-establishment or rehabilitation to restore the vegetative cover to maintain training realism and retard erosion. Rapid plant germination will help to shorten establishment times. Grasses and legumes are the two primary groups of plants used for revegetating training lands. Their germination times range from a few days up to a month.

Seed germination usually depends on the proper light, moisture and temperature conditions to activate the process. These factors are not always present at the desired levels in the usually inhospitable environments associated with training lands. Various hormonal, physical and chemical treatments have been used to promote seed germination in forage and vegetable crops. These treatments will decrease inherent germination times to take advantage of ephemeral optimum germination environments.

The objectives of this study were to investigate the effectiveness of ten seed treatments (including a control) in reducing the germination times of ten plant species commonly used for revegetating damaged ground.

Four of the ten treatments used in this study used the plant hormones gibberellic acid and kinetin. The role of plant hormones in germination has been extensively studied, and much of this work has concerned the gibberellins, of which gibberellic acid is one form. The gibberellic acid used in this study was GA_3. Gibberellins have been shown to be successful not only in breaking dormancy in some seeds but also in accelerating germination in non-dormant seeds (Bewley and Black 1982). The germination rate of a number of plants, notably lettuce, oats and barley, is markedly enhanced by treatment with gibberellins. The optimum application rates of gibberellins vary for different species of plants. Among monocotyledons, observations have been infrequent and generally restricted to food species such as oats and barley. There appears to be little evidence that gibberellins stimulate germination under optimum conditions; however, under suboptimum temperature and light conditions, germination of some grasses (e.g. Kentucky bluegrass and zoysiagrass) is enhanced (Beard 1973).

Cytokinins (kinetin is a synthetic cytokinin) have also been shown to stimulate germination in certain plants, although the evidence is less clear (Mayer and Poljakoff-Mayber 1989). Often these compounds appear to interact with other plant hormones present at the same time, such as gibberellins or abscisic acid (ABA), by counteracting their inhibitory effects (Bewley and Black 1982). Khan (1971) suggested that while gibberellins actually actively promote germination, the function of cytokinins is simply to suppress any inhibitors, such as ABA, to allow germination to proceed.

Five of the treatments were environmental. Of these, four involved soaking for 1 or 3 days in either hot water (40°C) or cold water (2°C). In the fifth treatment seeds were soaked overnight and then kept in a cold room at –5°C for a week.

Soaking seeds in water decreases the time to germination by softening or modifying hard seed coats, removing inhibitors and imbibing the seeds. For very hard seed coats, soaking in hot water may succeed if the cold water treatment is inadequate (Hartmann and Kester 1975).

Cold treatment is commonly used as a type of stratification to induce germination in certain seeds that require a period of low temperature for germination. These are largely seeds of woody trees and

shrubs (Hartmann and Kester 1975). It also brings about prompt and uniform germination in other species, such as switchgrass and deer tongue.

MATERIALS AND METHODS

Materials

The ten species selected for this study have characteristics useful for revegetating army training lands (App. A). The species were:

- Ladino clover [*Trifolium repens* L.]
- Birdsfoot trefoil [*Lotus corniculatus* L.]
- Buffalograss [*Buchloe dactyloides* Nutt.]
- Blend of perennial ryegrass cultivars [*Lolium perenne* L.]
- Timothy [*Phleum pratense* L.]
- Indian ricegrass [*Oryzopsis hymenoides* (R. and S.) Ricker]
- Tall fescue [*Festuca arundinacea* Schreb.]
- Hard fescue [*Festuca ovina* (L.) var. *durar*]
- Big bluegrass [*Poa ampla* Merrill]
- Switchgrass [*Panicum virgatum* L.].

Each of the seed types was exposed to ten treatments to stimulate germination, with three replications of each treatment. Five of these treatments were environmental, and four were hormonal. One was a control.

The chemicals used in the treatments were purchased from Sigma Chemical Co., kinetin commercial grade, stock no. K-3378, and gibberellic acid, stock No. G-1025. They were dissolved in distilled deionized water before use. The gibberellic acid was moderately soluble in water, but the kinetin had to be dissolved in a small (roughly 10% solution) amount of HCl before a stock solution could be made.

Treatments

The methods for the treatments were as follows.

1. Cold treatment

A small quantity of seeds was placed in a 500-mL beaker and soaked overnight in about 300 mL of distilled water. The seeds were counted into each of three petri dishes lined with moist filter paper. These dishes were then placed in an unlit cold room at -5°C for a week.

2. Warm water soak—1 day

A small quantity of seeds was placed in a 500-mL beaker, and about 300 mL of distilled water was added. The beakers were then put into an environmental chamber, lit by incandescent bulbs, at 40°C for 24 hours. At the end of this time the seeds were rinsed in distilled water and dried overnight at room temperature.

3. Warm water soak—3 days

The seeds were treated as above except that after 24 and 48 hours the water was drained and replaced with fresh distilled water at 40°C. After three days the seeds were rinsed and dried as above.

4. Cold water soak—1 day

The seeds were treated as in number 2 above except that the environmental chamber was kept at 2°C.

5. Cold water soak—3 days

The seeds were treated as in number 3 above except that the environmental chamber and fresh distilled water were kept at 2°C.

6. Gibberellic acid (GA_3)—200 ppm

The seeds were soaked in about 100 mL of a 200-ppm (approximately 5×10^{-4} M) solution of gibberellic acid potassium salt ($C_{19}H_{21}O_6K$) for 18 hours at room temperature. The wet seeds were put directly into prepared petri dishes.

7. Gibberellic acid (GA_3)—2000 ppm

The seeds were treated as above except the concentration of the GA was 2000 ppm (approximately 5×10^{-3} M).

8. Gibberellic acid (GA_3) plus kinetin

The seeds were treated as in number 7. At the end of the 18-hour period, the GA solution was drained off and about 100 mL of a 100-ppm (approximately 5×10^{-4} M) solution of kinetin was added. The seeds were soaked in this for three minutes and then placed immediately into prepared petri dishes.

9. Kinetin—100 ppm

The seeds were soaked in a 100-ppm solution of kinetin for about three minutes before being put into prepared petri dishes.

10. Control

The seeds were not treated.

Incubation

After the treatments three samples of 50 seeds from each treatment were counted into moist filter paper in 12.5-cm plastic petri dishes. The dishes were stacked three deep on a lab bench, with all treatments of the same species together. The germinated seeds were counted and discarded about three times a week for two weeks or until all seeds or the control had completely germinated. Water was added to the dishes as needed at the same time. At the end of two weeks, the ungerminated seeds were counted to obtain the actual number of seeds in each sample.

The students who tended the dishes and counted

the germinated seeds noticed that there was a fairly strong thermal gradient along the bench because of an outside door at one end. The result of this was that the dishes farthest from the door were warmer than those nearer to it and tended to become dry.

Two series of experiments, each containing five species, were run at a time. The first series (timothy, tall fescue, birdsfoot trefoil, switchgrass and big bluegrass) was run from 14 to 28 October, while the second series (perennial ryegrass, indian ricegrass, ladino clover, buffalograss and hard fescue) was run from 4 to 18 November. The five species in each series were laid out in the order given, starting from the end of the bench closest to the door:

RESULTS

Some of the dishes became contaminated with molds and bacterial growth (indicated by discolored patches). Table 1 is a qualitative comparison of the degree of these two types of contamination.

Tables of the raw data for all ten treatments and species are shown in Appendix B, along with graphs showing the cumulative percentages of germinated seeds throughout the period of observation.

Table 2 shows the qualitative summary of the relative effects of the various treatments on the ten species studied. Since we are concerned with the early germination of the seeds, effects noted refer

Table 1. Qualitative comparison of the degree of bacterial and mold contamination visible during the incubation of the seeds.

	Cold treatment	*Warm soak 1 day*	*Warm soak 3 day*	*Cold soak 1 day*	*Cold soak 3 day*	*GA 200 ppm*	*GA 2000 ppm*	*GA + kinetin*	*Kinetin*	*Control*
First series										
Timothy	0	0	0	0	0	0	0	0	0	0
Tall fescue	0	0	0	0	0	0	0	0	0	0
Birdsfoot trefoil	m	m	0	m	m	0	0	0	0	0
Switchgrass	0	0	0	0	0	0	0	0	0	0
Big bluegrass	0	0	0	0	0	0	0	mm	0	0
Second series										
Perennial ryegrass	0	0	0	0	0	m	m,d	m,d	0	m
Indian ricegrass	d	0	0	0	0	0	0	m,d	0	0
Ladino clover	m,d	0	0	m,d	0	0	0	m	d	ddd
Buffalograss	m	m	0	mm	m	m	mm	mm	m	m
Hard fescue	mmm	mmm	0	mmm	mmm	mmm	mmm	mmm	mmm,d	mm

m = molds
d = discoloration of paper
0 = neither

Table 2. Relative effectiveness of the treatments used in this study. The comparisons are expressed as proportions of the seeds from each treatment that had germinated on the first day when significant germination was observed as compared with the proportions of the seeds of the control that had germinated on the same day.

	Cold treatment	*Warm soak 1 day*	*Warm soak 3 day*	*Cold soak 1 day*	*Cold soak 3 day*	*GA 200 ppm*	*GA 2000 ppm*	*GA + kinetin*	*Kinetin*
Ladino clover	-			0	+ +	+ +	+ +	+ +	0
Birdsfoot trefoil					-	0	0	0	0
Buffalograss									
Perennial ryegrass		0		0	0	0	0	0	0
Timothy	0	0		0	0	0	0	0	0
Indian ricegrass	0	-		0	+	+	+ +	+ +	0
Tall fescue		0	0	+	0	+	+	0	0
Big bluegrass				+	0	+ +	+ + +	+ + +	+
Hard fescue		0	0	0	0	0	0	0	0
Switchgrass	+	+	+	+ +	+ +	+	+ +	+ +	+

+ + + More than 3.5 times control
+ + 2.5 to 3.5 times control
+ 1.5 to 2.5 times control
0.4 to 0.6 times control
- 0.2 to 0.4 times control
- - Less than 0.2 times control
0 No effect

primarily to the germination rates early in the incubation period rather than the overall number of seeds germinated by the end of the study. Graphs showing the effect of each treatment on the 10 species used in this study are given in Appendix C.

Birdsfoot trefoil

The rate and proportion of germinating seeds is sufficiently high in the untreated seeds of this species that treatment of any sort is not warranted. Some hormonal treatments did stimulate germination but only to a modest degree, while all of the environmental treatments greatly reduced the germination rate. The warm water treatment seems to have either killed most of the seeds or severely inhibited their germination.

Ladino clover

Like birdsfoot trefoil this species germinated extremely rapidly, and the use of any sort of treatment would seem to be unnecessary. However, where virtually instantaneous germination is desirable, this species might be a good choice, as we found nearly 100% germination in both gibberellin treatments on the first day.

Buffalograss

The seeds used in this experiment were 3–4 years old and were not hulled. Either of these factors may have contributed to the poor showing of this species, with less than 10% germinated after 2 weeks of incubation. The overall germination was so poor that we cannot make any valid conclusions about the effectiveness of the treatments.

Perennial ryegrass

None of the treatments showed a significant increase over the control. In fact, most of them appear to delay germination. As this species is well adapted for and frequently used in cool conditions, the conditions that prevailed in this study may unfairly reflect the value of the species in a revegetation program, since all species were kept at room temperature, much warmer than optimum for this plant. However, we consider its relative responses to the treatments valid.

Timothy

Like the two legumes, timothy appears to germinate quickly and completely enough that any sort of treatment to hasten germination would be unnecessary. In fact, several of the treatments inhibited germination to a greater or lesser degree.

Indian ricegrass

This species was strongly stimulated by all three treatments containing gibberellins, as well as by the 3-day cold water soak. This implies that a natural hormonal inhibitor is at work, counteracted by the gibberellins on the one hand and removed by soaking on the other. These four treatments produced twice the number of germinated seeds after 4 days as the control did. After 7 days it appears that germination in all treatments had virtually ended. By the end of the observation period at 14 days, the two gibberellin-only treatments still showed twice the proportion of the germinated seeds as the control, while the gibberellin plus kinetin was somewhat less than this and the three-day cold water soak showed little improvement over the control. This significant improvement in not only the speed of germination but also the final number of seedlings suggests that gibberellic acid treatment for this species might be worth the trouble and expense.

Tall fescue

These seeds showed an inconsistent response to both environmental and hormonal treatments. Germination was strongly inhibited by the cold treatment, little affected by the two 3-day soaks and unaffected by the two kinetin treatments. However, germination was strongly stimulated by both 1-day soaks and by both concentrations of gibberellic acid without kinetin. It is unfortunate that these seeds were not observed between the first and the fifth day after incubation began, as the data suggest that the gibberellin treatments may have strongly stimulated early germination.

Big bluegrass

The untreated seeds of this species germinated very poorly. At the end of 2 weeks only 25% of them had germinated. By contrast, the same seeds treated with high concentrations of gibberellic acid germinated quickly and in large numbers, achieving a germination rate of three times that of the control. The 1-day cold water soak was the only environmental treatment showing any promise.

Hard fescue

None of the treatments stimulated germination. Most of them had no effect, while three, including the two kinetin treatments, appeared to suppress germination. The germination rate of the control is high enough that pretreatment of this species would not be worthwhile.

Switchgrass

Unlike for the other species studied, all treatments stimulated germination. The least successful of the treatments produced nearly twice the germination rate of the control after four days. The greatest success was from the higher concentrations of gibberellic acid, with a germination rate more than three times that of the control.

DISCUSSION

Germination in a number of the species used in this study was improved, sometimes dramatically, by the gibberellic acid treatments, such as indian ricegrass, tall fescue, big bluegrass and switchgrass, three of which are native plants. While this is encouraging from the standpoint of establishing these grasses quickly in the field, there is also some evidence that GA treatment may produce abnormal seedling growth (Hartmann and Kester 1975). Before any large-scale use in the field, this possibility should be investigated.

Only two of our experimental grasses responded favorably to the kinetin treatment, big bluegrass and switchgrass. The combined GA/kinetin treatment showed a more dramatic effect than kinetin alone. but it seems likely that this is a result of the GA alone. The indifferent success of the kinetin treatment, compared with the excellent response to GA, suggests that research effort would be more profitably spent on the latter.

Soaking is most often used to speed germination in fairly large seeds with thick seed coats. The only seeds we used that had heavy seed coats were buffalograss. It is clear from the results shown in Appendix B that none of the soaking treatments improved germination in this species. It is clear, too, from the treatment comparison graphs in Appendix C that neither of the warm water soaks was particularly successful in any of the species, actually suppressing germination in most. However, the cold water soaks resulted in moderately increased germination in a few cases, notably switchgrass, big bluegrass and indian ricegrass. All of the seeds used in this study were relatively small; some were tiny. Therefore, softening of the seed coat probably contributed little to the modest benefits attributable to this treatment. It is more likely that the removal of inhibitors played the major role.

The cold treatment we used in this experiment was quite short, little more than a week. Its inhibitory effect was quite strong in several of the species, and only switchgrass showed significantly improved germination. It is possible that if the seeds were left in the cold for a longer period the germination rates might be quite different.

While it was not our original intention to observe microbial contamination patterns during the incubation period, observations made by the students have interesting implications and deserve mention. The first series of seeds, as shown in Table 1, shows little contamination; the second series shows a great deal. There is a strong likelihood that this apparent dichotomy is an artifact since the students had not been specifically instructed to watch for this sort of development at the start of the project but were told to note any observable contamination at the beginning of the second series. For this reason the molds noted in the first series were probably more conspicuous than the notations suggest since the students making the observations noted their occurrence without direction. Nevertheless, no valid conclusions can be drawn regarding the relative abundance of contaminants between the two series. There are, however, two observations that are very suggestive and may be worth following up with additional research.

First, there were neither molds nor discoloration noted in any of the samples treated with the 3-day warm water soak. The implication is that any spores in the seeds germinated during the soaking period and were killed by the subsequent drying. While it is also true that this treatment delayed germination in many species, it is possible that a soak at a somewhat lower temperature, e.g. 30°C, could have the same effect on the microbial contaminants while either stimulating germination or at least not retarding it. This antimicrobial treatment would be especially valuable when using seeds known to be prone to rotting.

The second observation is that the gibberellic acid plus kinetin treatment appears to stimulate microbial growth quite strongly. If this can be confirmed, it may prove possible to disinfect seeds before planting through a modified drying process similar to that used for the warm water soak. This could prove valuable for species such as big bluegrass, whose germination was inhibited by the warm water soak but stimulated by the GA-kinetin treatment.

CONCLUSIONS

The response of the ten species to environmental and hormonal stimuli was extremely varied, and it is likely that this diversity would exist in other revegetation candidates. Some species, such as ladino clover, birdsfoot trefoil and timothy, germinate

rapidly, and pretreatment of any sort seems unnecessary. The extremely fast germination of gibberellin-treated ladino clover may be useful for certain purposes, if subsequent growth is normal and healthy. This deserves further investigation.

In general the environmental treatments were relatively ineffective. While indian ricegrass, switchgrass and tall fescue responded well to the cold water soaks, for the most part these treatments either inhibited germination or had little effect.

The gibberellin treatments, on the other hand, produced some startling increases in germination rate, especially in big bluegrass and switchgrass. Since previous work has shown that the germination rate is strongly influenced by the concentration of the gibberellin solution used, it would be useful to conduct a follow-up study on some of the more promising species to determine the optimum solution molarity, whether the beneficial effects are retained when the seeds are germinated in soil, and whether subsequent seedling growth is normal and healthy. It may be worth trying to discover why the two most gibberellin-sensitive species are also the only two showing a positive response to kinetin.

In spite of its unremarkable performance in this experiment, buffalograss deserves further attention because of its wide range and tolerance, once established, of poor growing conditions (App. A). At the very least a parallel series of tests should be conducted using hulled seeds.

Another native grass, big bluegrass, is also a promising candidate for further study. Since this species has potential value in revegetation applications throughout the American West, further investigation into its response to various gibberellins and perhaps other hormones would be of value.

Finally, further study of a third native grass, switchgrass, would be of interest for a number of reasons. First, it is a good choice for revegetation projects because it occurs naturally in a wide variety of environments. Second, it is difficult to establish. Third, its germination is favorably influenced by virtually any treatment. Perhaps additional treatments should be investigated to find the easiest and most effective one for this species. And last, seven of the eight grasses used in this study are members of the same subfamily; switchgrass is the lone exception. Since it stands out among the other grasses studied as the one most amenable to pretreatment, it is possible that other closely related species may respond similarly and could provide valuable alternatives to species now commonly used for revegetation.

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APPENDIX A: CHARACTERISTICS OF THE SPECIES USED IN THIS STUDY

The following species were used in this study:

Family Leguminoseae
- Ladino clover [*Trifolium repens* L.]
- Birdsfoot trefoil [*Lotus corniculatus* L.]

Family Gramineae
- Subfamily Poaceae
  - Tribe Chlorideae
    - Buffalograss [*Buchloe dactyloides* Nutt.]
  - Tribe Hordeae
    - Blend of perennial ryegrass cultivars [*Lolium perenne* L.]
  - Tribe Agrostideae
    - Timothy [*Phleum pratense* L.]
    - Indian ricegrass [*Oryzopsis hymenoides* (R. and S.) Ricker]
  - Tribe Festuceae
    - Tall fescue [*Festuca arundinacea* Schreb.]
    - Hard fescue [*Festuca ovina* (L.) var. *durar*]
    - Big bluegrass [*Poa ampla* Merrill]
- Subfamily Panicoideae
  - Tribe Paniceae
    - Switchgrass [*Panicum virgatum* L.].

LEGUMES

Ladino clover (*Trifolium repens*)

This large type of white clover was first recorded in the United States in 1891. It has been gradually introduced into the western, northeastern, north-central and southeastern U.S. It spreads by stolons and is propagated by seed. Ladino clover does not bloom as early or as profusely as the smaller white clovers. It is not winter-hardy. It grows best in moist, temperate areas with light soils (Heath et al. 1973).

Birdsfoot trefoil (*Lotus corniculatus*)

This is a perennial forage legume native to Europe and parts of Asia. The many cultivars available vary in size, habit, time to flowering, hardiness and growth rate. In general, birdsfoot trefoil can tolerate a wide variety of soil types and conditions, preferring fertile, well-drained soils with a pH of 6.2 or higher. It has a well-developed taproot with numerous lateral branches in the top 30–60 cm of the soil. Plants may be propagated by root or stem cuttings and by seed. It requires 16 hours of daylight for full flowering, lacking which flowering is reduced and the plants have a more prostrate, rosette growth habit (Heath et al. 1973).

GRASSES

Buffalograss (*Buchloe dactyloides*)

This dioecious perennial is native to dry prairies and plains of west-central North America. It is the most important constituent of the short-grass prairies and is a semi-arid warm-season turfgrass. It spreads by profusely branching stolons that produce clumps of short culms from each node, resulting in a dense sod with a shallow root system. The seeds are borne in hard burrs that may produce a low germination percentage; this can be improved by chilling and dehulling. It has excellent resistance to drought and tolerance to submersion but poor shade tolerance. It grows well in soils with a high clay content but does not succeed in sandy soils. It is tolerant to alkali. It can be propagated by either sod pieces or seed (Gleason 1963, Beard 1973, Heath et al. 1973).

Perennial ryegrass (*Lolium perenne*)

The ryegrasses have the most rapid establishment rate of the commonly used cool-season turfgrasses. A native of Asia and North Africa, perennial ryegrass is a short-lived perennial in many regions but can persist indefinitely in benign temperature conditions. Best adapted to cool, moist conditions, it is generally not tolerant of extreme heat, drought or strongly acid soils. Though intolerant of extreme cold, some cultivars are available with improved low-temperature resistance. There are conflicting reports concerning its shade tolerance and success in wet or waterlogged soils. It is propagated by seed and is quick to germinate and become established. It has a fibrous root system.

Timothy (*Phleum pratense*)

Introduced from Europe, timothy is adapted to cool, humid climates, where it may persist as a perennial. It has a shallow fibrous root system and grows in bunches, with poor sod-forming capability.

It is intolerant of mowing. It has good low-temperature tolerance but poor tolerance of heat and drought. Unlike most other turfgrasses, it develops corms from lower internodes of the stem for storage of carbohydrates, forming in early summer and dying within a year. Propagation is by seed, with fairly rapid establishment (Beard 1973).

Indian ricegrass (*Oryzopsis hymenoides*)

This cool-season native perennial is confined to north-central areas of the U.S. It is a drought-tolerant species of plains and deserts found growing in dry sandy and silty soils and disturbed sites. It starts growth in early spring (Stubbendieck 1986).

Tall fescue (*Festuca arundinacea*)

This cool-season perennial turfgrass, introduced from Europe, is long-lived in the transitional zone between cool, humid and warm, humid regions. Its root system is extensive, coarse and deeper than that of most cool-season turfgrasses. It has better drought and wear tolerance than most turfgrasses. It is prone to low-temperature injury in cold, humid areas and has intermediate shade tolerance. It produces short rhizomes, but most new shoots arise from the crown rather than the nodes of the rhizomes. Propagation is by seed. It tolerates wet soil and flourishes in the spring and fall (Sprague 1970, Beard 1973).

Hard fescue (*Festuca ovina* var. *durar*)

This cool-season perennial was introduced from Europe and has a tufted habit and extensive root system. It has moderate drought tolerance and high moisture tolerance and is adapted for shaded conditions. It is propagated by seed. It will not tolerate mowing at less than 1 inch. The *durar* cultivar is well adapted to cool, subhumid and semi-arid regions. It is more uniform, drought resistant and shade tolerant than other common fescues (Beard 1973).

Big bluegrass (*Poa ampla*)

This vigorous, perennial bunchgrass is native to North America, occurring throughout the West (Heath et al. 1973).

Switchgrass (*Panicum virgatum*)

Native to North America and widespread almost everywhere east of the Rocky Mountains, this grass is found in open woods, prairies, dunes, shores and brackish marshes. It is a tall, perennial sod-forming grass spreading slowly by short rhizomes. It is good for hay, summer pasture and erosion control. Propagation is by seed (Gleason 1963, Heath et al. 1973).

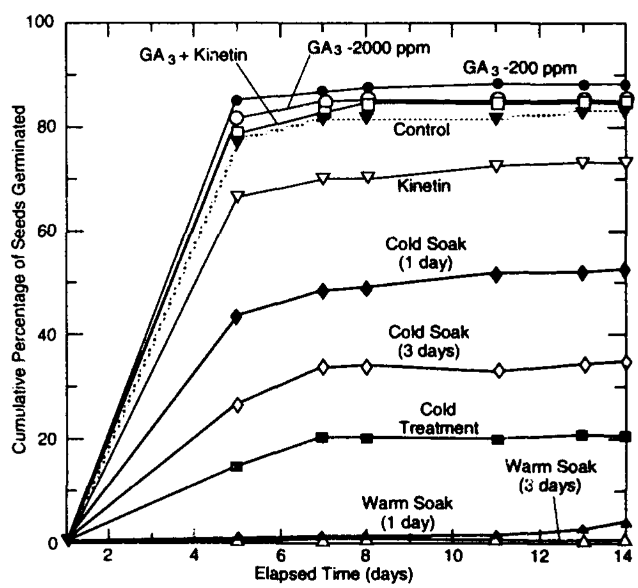
APPENDIX B: DATA TABLES AND SPECIES RESPONSE GRAPHS*

Birdsfoot trefoil

Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
		Elapsed time (days) from start of incubation period															
								Seeds germinated after time noted									
1 (cold	311*	0				39		8	0			0		1	0	65	113
treatment)	312*	0				42		15	0			0		1	0	38	96
	313*	0				8		12	0			0		0	0	77	97
2 (warm	321	0				0		0	0			0		0	0	48	48
soak—1 day)	322	0				1		1	0			0		1	1	46	50
	323	0				0		0	0			0		1	1	44	46
3 (warm	331	0				0		1	0			0		0	0	48	49
soak—3 days)	332	0				0		0	0			0		0	0	44	44
	333	0				0		0	0			0		0	0	49	49
4 (cold	341	0				20		3	0			1		0	0	26	50
soak—1 day)	342	0				25		2	0			2		0	1	19	49
	343	0				19		2	1			1		0	0	25	48
5 (cold	351	0				13		2	0			0		0	0	32	47
soak—3 days)	352†	0															0
	353	0				12		5	0			0		1	0	30	48
6 (GA_3—	361	0				38		0	1			1		0	0	10	50
200 ppm)	362	0				43		2	0			0		0	0	3	48
	363	0				47		0	0			0		0	0	5	52
7 (GA_3—	371	0				45		3	1			0		0	0	10	59
2000 ppm)	372	0				43		0	0			0		0	0	9	52
	373	0				46		2	0			0		0	0	6	54
8 (GA_3 +	381	0				38		3	0			0		0	0	10	51
kinetin)	382	0				44		1	3			0		0	0	6	54
	383	0				46		1	0			0		0	0	9	56
9 (kinetin)	391	0				35		1	0			0		1	0	10	47
	392	0				28		3	0			1		0	0	16	48
	393	0				35		2	0			2		0	0	14	53
0 (Control)	301	0				40		3	0			0		1	0	3	47
	302	0				37		1	0			0		0	0	15	53
	303	0				42		2	0			0		1	0	9	54
																Average	50.2
								Percentage of seeds germinated (cumulative)									
1		0				14		20	20			20		21	21		
2		0				1		1	1			1		3	4		
3		0				0		1	1			1		1	1		
4		0						48	49			52		52	52		
5		0				26		34	34			34		35	35		
6		0				85		87	87			88		88	88		
7		0				81		84	85			85		85	85		
8		0				79		83	84			84		84	84		
9		0				66		70	70			72		73	73		
0		0				78		82	82			82		83	83		

* During the overnight soak, about half of these seeds imbibed while half did not. Two sets of plates were therefore prepared. There was no difference between them.

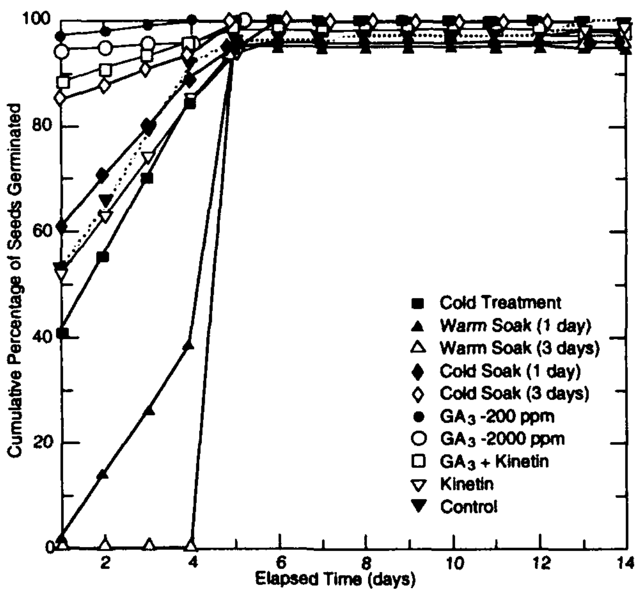
† Plate 352 was lost; no data are available.



* The tables contain the unprocessed data obtained during this study and the cumulative percent germinated on each day counts were done. The associated graphs show the cumulative percentages of germinated seeds throughout the period of observation.

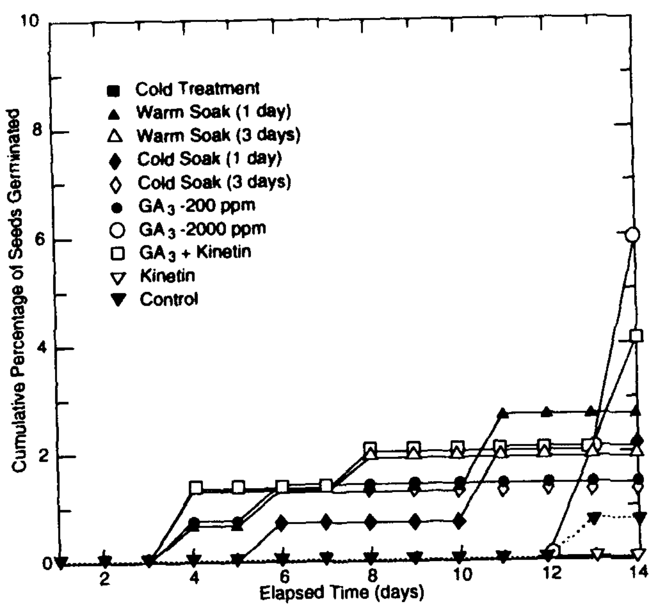
Ladino clover

Treatment	Plate no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
					Seeds germinated after time noted												
1 (cold treatment)	811	13			21	5	6									0	45
	812	14			26	3	2									0	45
	813	29			12	5										0	46
2 (warm soak—1 day)	821	0			19	27	0	0	0			0		0		3	49
	822	2			20	28	0	0	0			0		0		2	52
	823	1			15	28	0	0	0			0		0		2	46
3 (warm soak—3 days)	831	0			0	50	1	0	0			0		0		1	52
	832	0			0	49	0	0	0			0		0		2	51
	833	0			0	52	1	0	0			0		0		2	55
4 (cold soak—1 day)	841	34			13	1	0	0	0			0		0		5	53
	842	31			19	5	0	0	0			0		0		2	57
	843	32			14	4										0	50
5 (cold soak—3 days)	851	41			7	6										0	54
	852	48			2	2										0	52
	853	44			5	2										0	51
6 (GA$_3$—200 ppm	861	51														0	51
	862	49			2											0	51
	863	47			2											0	49
7 (GA$_3$—2000 ppm)	871	50														0	50
	872	45			2	2	1									0	50
	873	47			0	3										0	50
8 (GA$_3$ + kinetin)	881	47			0	0	0	0	0			0		0		2	49
	882	46			3	1										0	50
	883	40			8	3										0	51
9 (kinetin)	891	30			21	2	0	0	0			0		1		1	55
	892	18			16	9	6	0	0			0		0		2	51
	893	36			17	3										0	56
0 (Control)	801	28			14	1	1	0	0			0		1		0	45
	802	21			21	4	0	0	1			0		2		0	49
	803	27			22	0	0	0	0			0		1		0	50
																Average	51.0
					Percentage of seeds germinated (cumulative)												
1		41			85	94	103	103	103			103		103			
2		2			39	95	95	95	95			95		95			
3		0			0	96	97	97	97			97		97			
4		61			89	96	96	96	96			96		96			
5		85			94	100	100	100	100			100		100			
6		97			101	101	101	101	101			101		101			
7		95			97	102	104	104	104			104		104			
8		89			96	99	99	99	99			99		99			
9		52			85	94	99	99	99			99		100			
0		53			92	96	97	97	97			97		100			



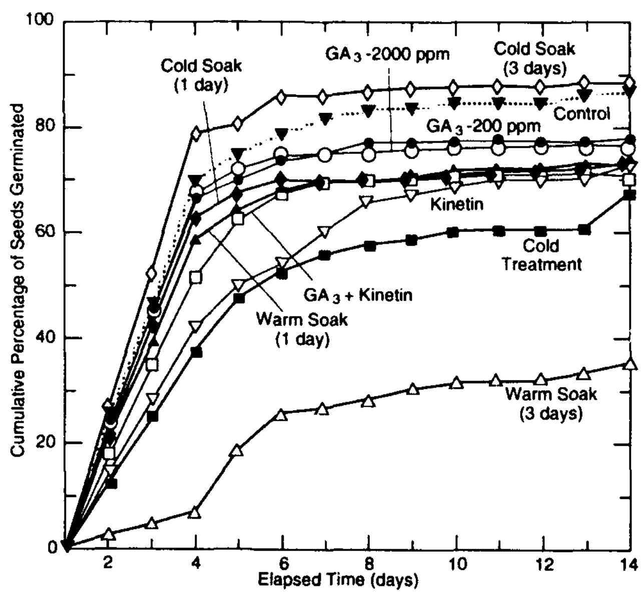
Buffalograss

Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
Seeds germinated after time noted																	
1 (cold treatment)	911	0			0									0	0	51	51
	912	0			0		0								0	50	50
	913	0			0		0							0	0	51	51
2 (warm soak—1 day)	921	0			1		0	0						0	0	49	51
	922	0			0		1	0	0					0	0	50	51
	923	0			0		0	0	0			1		0	0	51	52
3 (warm soak—3 days)	931	0			1		0	0	0			0		0	0	52	53
	932	0			1		0	0	1			0		0	0	50	52
	933	0			0		0	0	0			0		0	0	57	57
4 (cold soak—1 day)	941	0			0		0	0	0			2		0	0	47	49
	942	0			0		0	0	0			0		0	0	51	51
	943	0			0		1	0	0			0		0	0	49	50
5 (cold soak—3 days)	951	0			0		0	0	0			0		0	0	40	40
	952	0			1		0	0	0			0		0	0	51	52
	953	0			1		0	0	0			0		0	0	52	53
6 (GA₃—200 ppm)	961	0			1		0	0	0			0		0	0	49	50
	962	0			0		1	0	0			0		0	0	50	51
	963	0			0		0	0	0			0		0	0	50	50
7 (GA₃—2000 ppm)	971	0			0		0	0	0			0		3	0	49	52
	972	0			0		0	0	0			0		0	0	50	50
	973	0			0		0	0	0			0		0	2	48	50
8 (GA + kinetin)	981	0			1		0	0	0			0		0	1	48	50
	982	0			1		0	0	0			0		0	1	48	50
	983	0			0		0	0	1			0		0	0	48	49
9 (kinetin)	991	0			0		0	0	0			0		0	0	52	52
	992	0			0		0	0	0			0		0	0	51	51
	993	0			0		0	0	0			0		0	0	53	53
0 (Control)	901	0			0		0	0	0			0		1	0	49	50
	902	0			0		0	0	0			0		0	0	50	50
	903	0			0		0	0	0			0		0	0	51	51
																Average	50.7
Percentage of seeds germinated (cumulative)																	
1		0			0		0	0	0			0		0	0		
2		0			1		1	1	1			3		3	3		
3		0			1		1	1	2			2		2	2		
4		0			0		1	1	1			2		2	2		
5		0			1		1	1	1			1		1	1		
6		0			1		1	1	1			1		1	1		
7		0			0		0	0	0			0		2	6		
8		0			1		1	1	2			2		2	4		
9		0			1		0	0	0			0		0	0		
0		0			1		0	0	0			0		1	1		



Perennial ryegrass

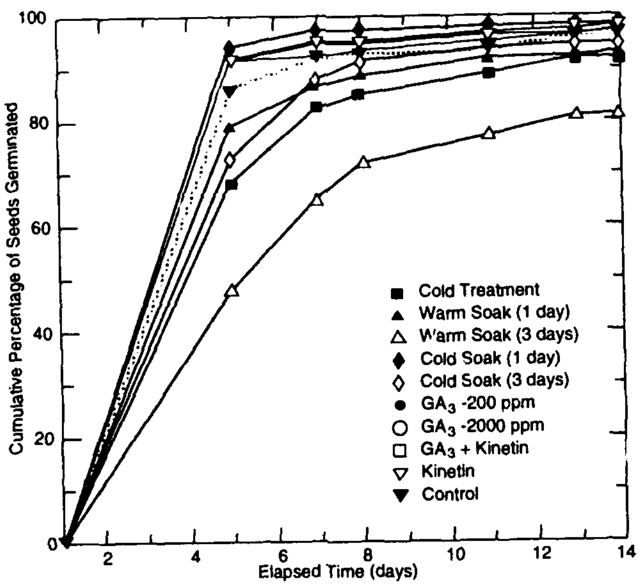
Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
									Elapsed time (days) from start of incubation period								
									Seeds germinated after time noted								
1 (cold	611	0			18	3	1	0	1			2		0	4	22	51
treatment)	612	0			24	3	2	3	2			1		0	2	14	51
	613	0			13	9	4	2	0			1		0	4	13	46
2 (warm	621	0			34	1	2	0	0			2		1	0	11	51
soak 1 day)	622	0			21	6	2	2	0			1		0	0	18	50
	623	0			31	0	0	1	0			1		0	0	13	46
3 (warm	631	0			4	8	2	0	0			4		1	2	30	51
soak 3 days)	632	0			2	5	3	1	0			2		0	1	37	50
	633	0			4	5	6	1	0			2		1	0	32	51
4 (cold	641	0			26	3	1	0	0			1		0	0	18	49
soak 1 day)	642	0			31	3	0	0	0			1		0	1	11	47
	643	0			32	[illegible]	1	0	0			1		0	2	10	47
5 (cold	651	0			41	1	0	0	1			0		0	0	5	48
soak 3 days)	652	0			32	2	2	0	0			0		1	0	9	46
	653	0			36	0	3	0	0			1		0	0	5	45
6 (GA3–	661	0			36	0	0	0	2			0		0	0	12	50
200 ppm)	662	0			34	0	2	0	0			0		0	1	12	[illegible]
	663	0			28	5	2	2	0			0		0	0	12	
7 (GA3–	671	0			39	0	1	0	0			1		0	0	5	
2000 ppm)	672	0			30	4	1	0	0			0		0	0	19	[illegible]
	673	0			32	4	2	1	0			1		0	0	13	53
8 (GA3 +	681	0			31	0	1	0	0			0		0	0	17	49
kinetin)	682	0			13	11	4	3	0			1		0	0	14	46
	683	0			30	4	2	0	0			0		0	0	11	47
9 (kinetin)	691	0			34	6	2	1	1			0		0	0	6	50
	692	0			27	2	2	2	0			1		0	1	12	47
	693	0			0	4	2	7	7			7		1	3	22	53
0 (Control)	601	0			34	0	1	0	0			0		1	0	6	42
	602	0			27	4	3	0	2			2		1	0	10	49
	603	0			36	4	1	0	0			0		0	1	8	50
																Average	48.8
									Percentage of seeds germinated (cumulative)								
1		0			37	47	52	56	58			60		60	67		
2		0			59	63	67	69	69			72		73	73		
3		0			7	18	26	26	26			32		33	35		
4		0			62	67	69	69	69			71		71	74		
5		0			78	80	86	86	87			87		88	88		
6		0			66	70	74	75	77			77		77	78		
7		0			67	72	74	75	75			76		76	76		
8		0			52	63	68	70	70			70		70	70		
9		0			42	50	54	60	65			70		70	73		
0		0			69	75	78	82	83			84		86	87		



Timothy

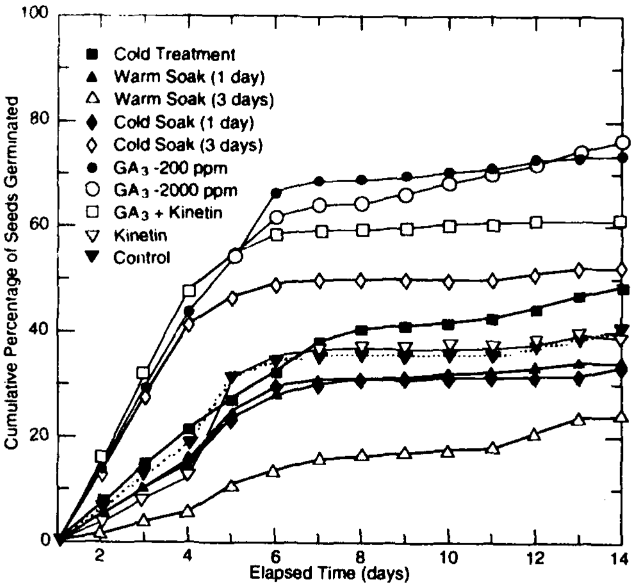
Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
Seeds germinated after time noted																	
1 (cold treatment)	111	0				28		11	2			3		3		5	52
	112	0				32		5	1			2		1		7	48
	113	0				40		5	1			1		0		1	48
2 (warm soak—1 day)	121	0				45		2	1			0		0		3	51
	122	0				34		6	2			2		0		7	51
	123	0				42		4	0			3		0	1	2	52
3 (warm soak—3 days)	131	0				32		5	3			2		0		1	43
	132	0				15		13	4			3		1		14	50
	133	0				18		6	3			2		4		13	46
4 (cold soak—1 day)	141	0				45		2	0			1		0		1	49
	142	0				46		2	0			0		0		2	50
	143	0				49		0	0			0		0		1	50
5 (cold soak—3 days)	151	0				46		1	0			0		0		3	50
	152	0				47		1	0			2		0		2	52
	153	0				18		21	6			1		2		4	52
6 (GA_3—200 ppm)	161	0				48		0	0			1		0		1	50
	162	0				44		1	2			3		0		2	52
	163	0				45		1	0			0		2		1	49
7 (GA_3—2000 ppm)	171	0				47		1	1			0		2		4	55
	172	0				48		0	0			0		0		2	50
	173	0				45		4	0			0		0		0	49
8 (GA_3 + kinetin)	181	0				43		3	0			0		0		2	48
	182	0				46		3	0			0		0		2	51
	183	0				47		1	0			1		0		2	51
9 (kinetin)	191	0				44		1	0			1		0	1		47
	192	0				44		3	0			2		0		0	49
	193	0				46		1	0			0		0		4	51
0 (Control)	101	0				41		4	0			1		1		3	50
	102	0				42		4	0			1		3		1	51
	103	0				44		1	0			0		0		2	47
																Average	49.8
Percentage of seeds germinated (cumulative)																	
1		0				68		82	85			89		91	91		
2		0				79		86	88			92		92	92		
3		0				48		65	72			77		80	80		
4		0				94		97	97			97		97	97		
5		0				72		87	91			93		94	94		
6		0				91		92	93			96		97	97		
7		0				91		94	95			95		96	96		
8		0				91		95	95			96		96	96		
9		0				91		95	95			97		97	97		
0		0				86		92	92			93		96	96		

Column headings 1–14: Elapsed time (days) from start of incubation period



Indian ricegrass

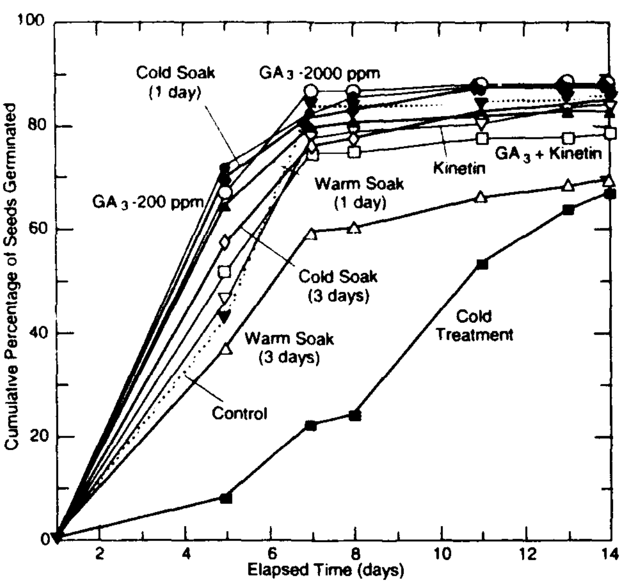
Treatment	Plate no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
Seeds germinated after time noted																	
1 (cold	711	0			14	4	2	0	0			1		0	0	29	50
treatment)	712	0			7	3	1	3	1			2		2	1	31	51
	713	0			11	2	5	5	3			0		0	0	25	51
2 (warm	721	0			7	2	5	0	1			1		1	0	36	53
soak—1 day)	722	0			9	5	1	1	0			1		0	0	35	52
	723	0			7	7	0	2	0			0		0	0	32	48
3 (warm	731	0			3	4	2	1	0			2		0	0	39	51
soak—3 days)	732	0			4	2	0	1	1			0		3	0	40	51
	733	0			2	2	2	1	0			0		0	0	44	51
4 (cold	741	0			6	4	4	0	0			0		0	1	36	51
soak—1 day)	742	0			9	6	2	1	1			1		0	0	31	51
	743	0			8	3	3	0	0			0		0	0	38	52
5 (cold	751	0			24	3	0	1	0			0		1	0	17	46
soak—3 days)	752	0			21	3	2	0	0			0		0	0	26	52
	753	0			15	1	2	0	0			0		1	0	29	48
6 (GA_3—	761	0			23	6	10	0	0			0		2	0	11	52
200 ppm)	762	0			23	7	3	0	0			1		0	0	15	49
	763	0			20	3	6	3	0			2		1	0	16	51
7 (GA_3—	771	0			27	2	5	1	0			0		0	0	14	49
2000 ppm)	772	0			28	1	2	1	0			2		0	0	17	51
	773	0			17	6	6	1	0			7		2	1	12	52
8 (GA_3 +	781	0			22	5	4	0	0			1		0	0	20	52
kinetin)	782	0			26	5	1	0	0			0		0	0	17	49
	783	0			23	1	1	1	0			1		0	0	22	49
9 (kinetin)	791	0			7	6	3	1	0			0		1	0	33	51
	792	0			6	14	3	1	0			0		1	0	25	50
	793	0			6	8	0	0	0			0		0	0	36	50
0 (Control)	701	0			9	3	1	[illegible]	0			0		1	1	33	49
	702	0			11	6	2	0	0			0		1	0	32	52
	703	0			8	10	2	0	0			0		2	0	27	49
																Average	50.3
Percentage of seeds germinated (cumulative)																	
1		0			21	27	32	38	40			42		46	48		
2		0			15	24	28	30	31			32		34	34		
3		0			6	11	14	16	16			18		24	24		
4		0			15	23	29	30	31			31		31	33		
5		0			41	46	49	49	49			49		52	52		
6		0			43	54	66	68	68			70		73	73		
7		0			48	53	62	64	64			70		74	76		
8		0			47	55	59	59	59			61		61	61		
9		0			13	31	35	36	36			36		38	38		
0		0			19	31	35	35	35			35		38	40		



Tall fescue

Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
								Seeds germinated after time noted									
1 (cold	211	0				3		5	0			15		3	2	21	49
treatment)	212	0				6		6	3			12		5	2	17	51
	213	0				3		11	0			18		8	1	13	54
2 (warm	221	0				28		11	1			1		0	0	9	50
soak—1 day)	222	0				35		6	1			0		0	1	8	51
	223	0				33		5	0			1		1	0	9	49
3 (warm	231	0				17		11	0			2		0	1	16	47
soak—3 days)	232	0				15		10	0			2		1	0	17	45
	233	0				20		11	1			4		2	1	10	49
4 (cold	241	0				30		8	2			3		0	0	5	48
soak—1 day)	242	0				32		4	0			1		0	0	12	49
	243	0				37		7	0			1		0	0	2	47
5 (cold	251	0				28		4	1			2		1	1	10	47
soak—3 days)	252	0				29		9	1			1		0	0	6	46
	253	0				22		13	0			4		1	0	6	46
6 (GA_3—	261	0				33		4	0			2		0	0	5	44
200 ppm)	262	0				31		5	3			0		0	0	7	46
	263	0				37		6	1			1		0	0	6	51
7 (GA_3—	271	0				38		6	0			1		0	0	6	51
2000 ppm)	272	0				32		14	0			1		0	0	4	51
	273	0				31		10	0			0		0	0	9	50
8 (GA +	281	0				23		13	0			2		0	1	10	49
kinetin)	282	0				28		10	0			2		0	0	12	52
	283	0				26		12	0			0		0	0	11	49
9 (kinetin)	291	0				23		15	0			2		0	1	6	47
	292	0				18		13	1			0		2	0	9	43
	293	0				23		15	1			0		1	1	7	48
0 (Control)	201	0				18		23	0			1		0	1	9	52
	202	0				21		19	0			0		1	0	6	47
	203	0				22		16	0			0		0	0	6	44
																Average	48.4
								Percentage of seeds germinated (cumulative)									
1		0				8		22	24			53		63	67		
2		0				64		79	80			81		82	83		
3		0				37		59	60			66		68	69		
4		0				69		82	83			87		87	87		
5		0				57		76	77			82		84	84		
6		0				72		82	85			87		87	87		
7		0				66		86	86			87		87	87		
8		0				51		75	75			77		77	78		
9		0				46		77	79			80		83	84		
0		0				43		83	83			84		85	85		

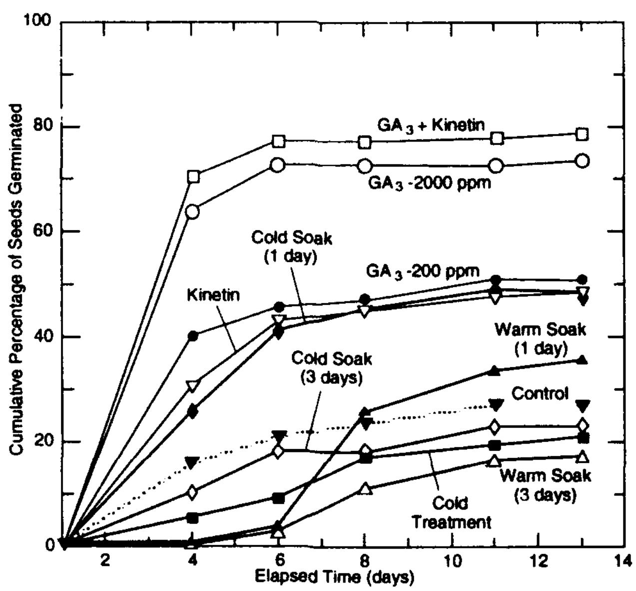
Column heading over days 1–14: *Elapsed time (days) from start of incubation period*



Big bluegrass

Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
Seeds germinated after time noted																	
1 (cold treatment)	511	0			5		4		3			0		0		35	47
	512	0			3		0		4			2		2		40	51
	513	0			0		1		5			2		0		44	52
2 (warm soak—1 day)	521	0			0		2		8			2		1		42	55
	522	0			0		0		9			8		0		33	50
	523	0			1		3		16			2		2		25	49
3 (warm soak—3 days	531	0			0		0		2			5		1		42	50
	532	0			0		3		4			2		0		38	47
	533	0			0		1		6			1		0		39	47
4 (cold soak—1 day)	541	0			11		10		1			0		0		27	49
	542	0			12		5		0			2		0		30	49
	543	0			14		7		5			2		0		18	46
5 (cold soak—3 days)	551	0			6		3		0			5		0		36	50
	552	0			4		2		0			1		0		44	51
	553	0			5		6		0			1		0		35	47
6 (GA_3—200 ppm)	561	0			14		4		0			3		0		21	42
	562	0			18		3		0			0		0		25	46
	563	0			23		1		2			2		0		21	49
7 (GA_3—2000 ppm)	571	0			40		3		0			1		0		6	50
	572	0			39		6		0			0		0		15	60
	573	0			28		6		0			0		0		26	60
8 (GA + kinetin)	581	0			38		6		0			2		0		13	59
	582	0			34		3		0			0		0		14	51
	583	0			40		2		0			0		0		8	50
9 (kinetin)	591	0			9		10		3			3		0		25	50
	592	0			17		1		0			1		1		25	45
	593	0			17		7		0			0		0		23	47
0 (Control)	501	0			8		3		0			2		0		32	45
	502	0			7		1		0			0		0		34	42
	503	0			7		3		4			3		0		35	52
																Average	49.6
Percentage of seeds germinated (cumulative)																	
1		0			6		9		17			20		21			
2		0			1		4		26			34		36			
3		0			0		3		11			17		17			
4		0			26		41		45			48		48			
5		0			10		18		18			22		22			
6		0			40		46		47			51		51			
7		0			64		73		73			73		73			
8		0			70		77		77			78		78			
9		0			31		43		45			48		49			
0		0			16		21		23			27		27			

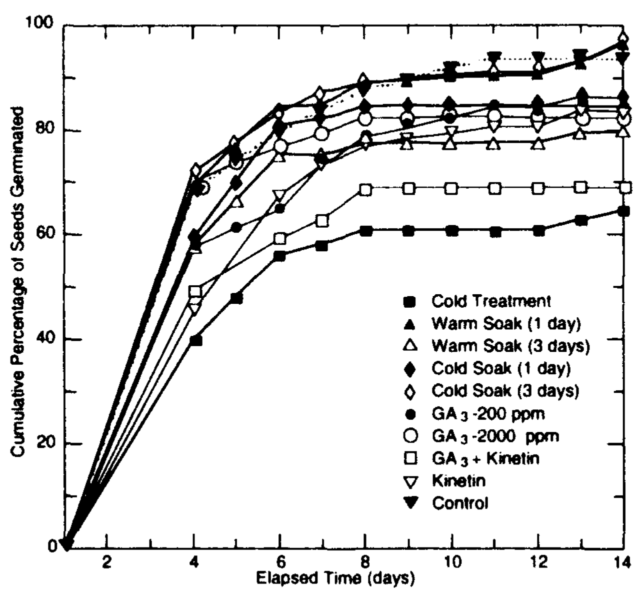
Column heading over days 1–14: *Elapsed time (days) from start of incubation period*



Hard fescue

Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total
		Seeds germinated after time noted															
1 (cold	1011	0			26		5	1	1			0		1	0	17	51
treatment)	1012	0			23		6	0	2			0		1	0	21	53
	1013	0			12		13	1	1			0		1	1	19	48
2 (warm	1021	0			32		9	0	1			0		0	0	9	51
soak—1 day)	1022	0			43		4	0	1			1		0	0	1	50
	1023	0			30		10	0	4			0		1	2	3	50
3 (warm	1031	0			25		10	0	3			0		0	0	11	49
soak—3 days)	1032	0			28		10	0	1			0		0	0	14	53
	1033	0			22		11	0	4			0		2	0	11	50
4 (cold	1041	0			24		10	1	0			0		0	0	15	50
soak—1 day)	1042	0			31		13	0	0			0		0	0	6	50
	1043	0			32		8	0	1			0		0	0	6	47
5 (cold	1051	0			39		3	2	1			0		1	1	4	51
soak—3 days)	1052	0			37		6	0	0			1		1	3	6	54
	1053	0			32		8	0	1			0		0	0	5	46
6 (GA_3—	1061	0			22		4	0	4			3		0	0	17	50
200 ppm)	1062	0			29		4	6	1			0		0	0	13	53
	1063	0			43		4	3	0			0		1	0	7	58
7 (GA_3—	1071	0			36		2	0	0			0		0	0	13	51
2000 ppm)	1072	1			40		3	1	2			0		0	0	6	52
	1073	1			35		6	2	1			0		0	0	15	59
8 (GA_3 +	1081	0			9		8	2	2			0		0	0	30	51
kinetin)	1082	0			39		6	2	5			0		0	0	10	62
	1083	0			36		2	2	0			0		0	0	13	53
9 (kinetin)	1091	0			19		11	5	2			2		1	0	8	48
	1092	0			23		7	0	0			1		2	0	15	48
	1093	0			25		13	1	0			0		0	0	11	50
0 (Control)	1001	0			36		5	2	0			3		0	0	5	51
	1002	0			37		10	0	0			0		0	0	6	53
	1003	0			33		2	0	2			0		0	0	13	50
																Average	51.4
		Percentage of seeds germinated (cumulative)															
1		0			40		56	58	60			60		62	65		
2		0			70		85	85	89			91		93	97		
3		0			58		75	75	78			78		80	80		
4		0			59		80	82	84			84		84	84		
5		0			72		83	87	89			91		93	96		
6		0			58		65	73	78			84		86	86		
7		1			70		77	79	82			82		82	82		
8		0			49		59	63	69			69		69	69		
9		0			46		67	73	77			81		84	84		
0		0			69		80	84	88			93		93	93		

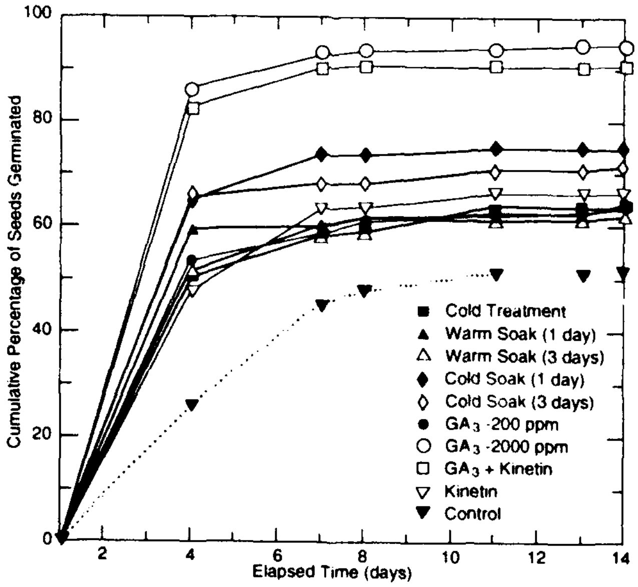
Elapsed time (days) from start of incubation period



Switchgrass

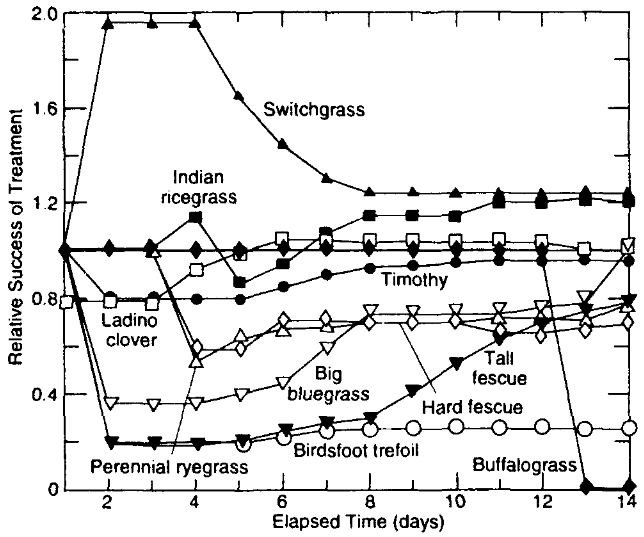
Treatment	Plate no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remaining	Total*
		Elapsed time (days) from start of incubation period															
		Seeds germinated after time noted															
1 (cold treatment)	1011	0			26		5	1	1			0		1	0	17	51
	411	0			27			4	0			3		0	0	16	50
	412	0			28			2	0			1		0	0	19	50
	413	0			21			6	1			2		0	0	20	50
2 (warm soak—1 day)	421	0			31			1	0			0		0	0	18	50
	422	0			29			0	2			0		0	0	19	50
	423	0			29			0	0			1		0	0	20	50
3 (warm soak—3 days)	431	0			25			4	0			0		0	0	21	50
	432	0			29			5	0			1		0	0	15	50
	433	0			23			4	0			1		0	1	21	50
4 (cold soak—1 day)	441	0			31			2	0			1		0	0	16	50
	442	0			34			6	0			0		0	0	10	50
	443	0			32			5	0			1		0	0	12	50
5 (cold soak—3 days)	451	0			37			1	0			0		0	0	12	50
	452	0			32			2	0			1		0	0	14	49
	453	0			28			1	0			3		0	1	17	50
6 (GA_3—200 ppm)	461	0			20			1	1			0		0	1	27	50
	462	0			33			4	2			1		0	1	9	50
	463	0			27			3	0			2		0	0	18	50
7 (GA_3—2000 ppm)	471	0			43			3	0			0		0	0	4	50
	472	0			40			4	1			1		0	0	4	50
	473	0			46			3	0			0		1		0	50
8 (GA + kinetin)	481	0			40			4	0			0		0	0	6	50
	482	0			48			8	1			0		0	0	0	57
	483	0			42				0			0		0	0	8	50
9 (kinetin)	491	0			34			2	0			3		0	0	11	50
	492	0			22			11	0			1		0	0	16	50
	493	0			16			10	0			0		0	0	24	50
0 (Control)	401	0			8			13	2			0		0	0	27	50
	402	0			9			13	0			2		0	0	26	50
	403	0			22			3	2			3		0	0	20	50
																Average	50.2
		Percentage of seeds germinated (cumulative)															
1		0			51			59	59			63		63		63	
2		0			59			60	61			62		62		62	
3		0			51			60	60			61		61		62	
4		0			65			73	73			75		75		75	
5		0			65			68	68			70		70		71	
6		0			53			59	61			63		63		64	
7		0			86			93	93			94		95		95	
8		0			83			90	91			91		91		91	
9		0			48			63	63			66		66		66	
0		0			26			45	48			51		51		51	

* Since the seeds remaining were only counted for two samples of this species, sample total was assumed to be 50, and average and standard deviation were not calculated.

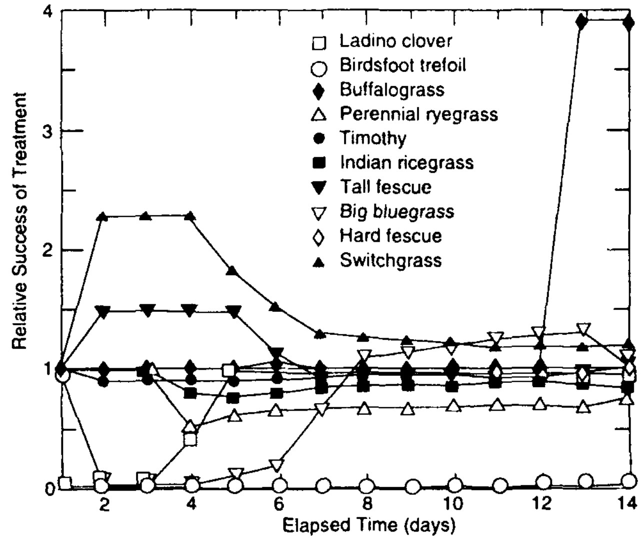


APPENDIX C: RELATIVE EFFECTIVENESS OF EACH OF THE NINE TREATMENTS USED ON THE TEN SPECIES STUDIED

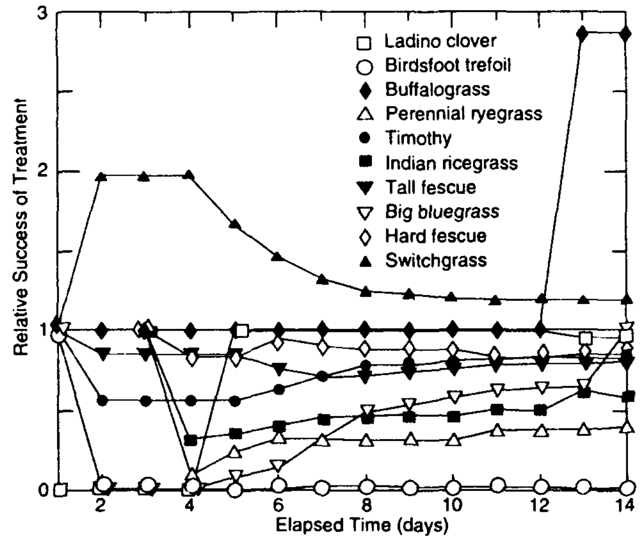
The y-values of these graphs are calculated by dividing the cumulative percentage of seeds germinated each day by the cumulative percentage of seeds of the control germinated on the same day. Thus, a value of 2 means that the treatment had twice the proportion of seeds germinated as the control did, while a value of 0.5 means that the treatment had only half the proportion as the control.



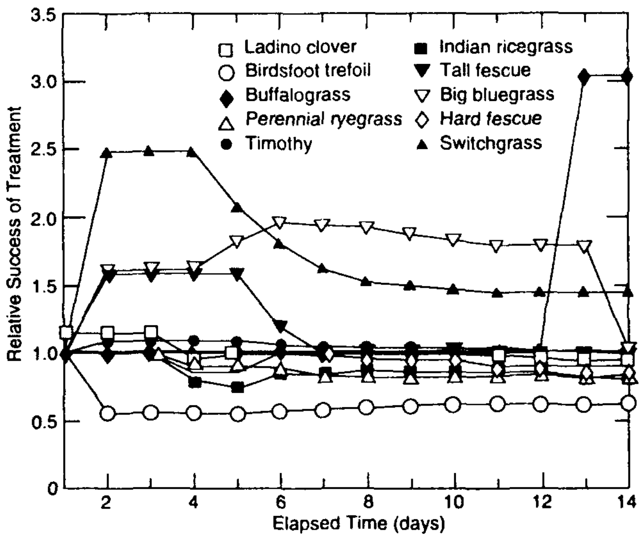
Cold treatment.



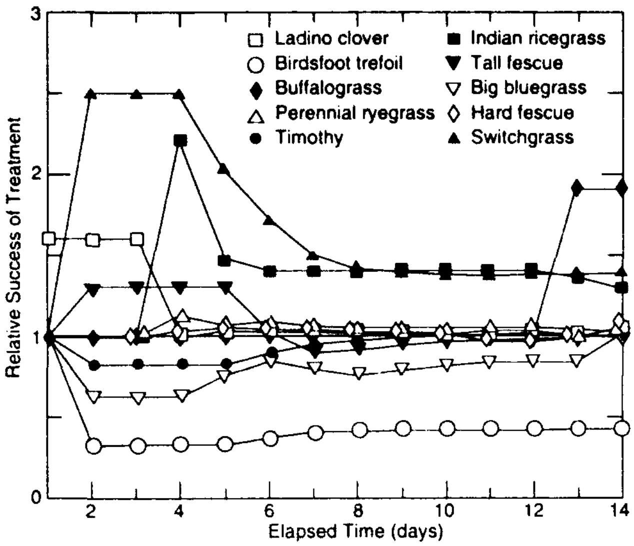
Warm soak—1 day.



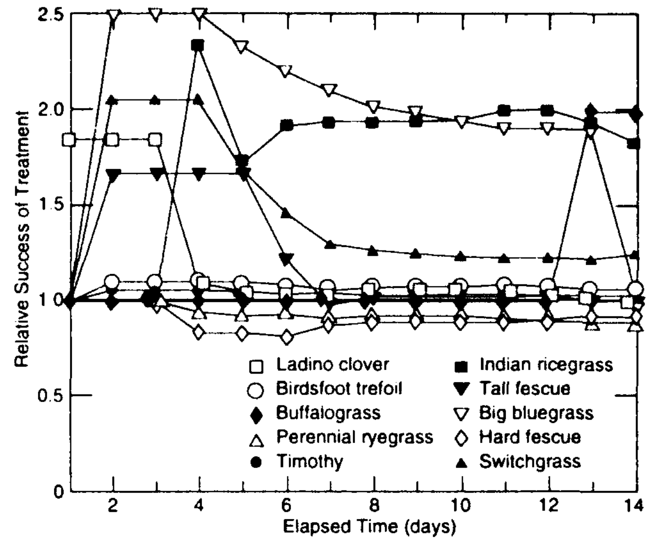
Warm soak—3 days.



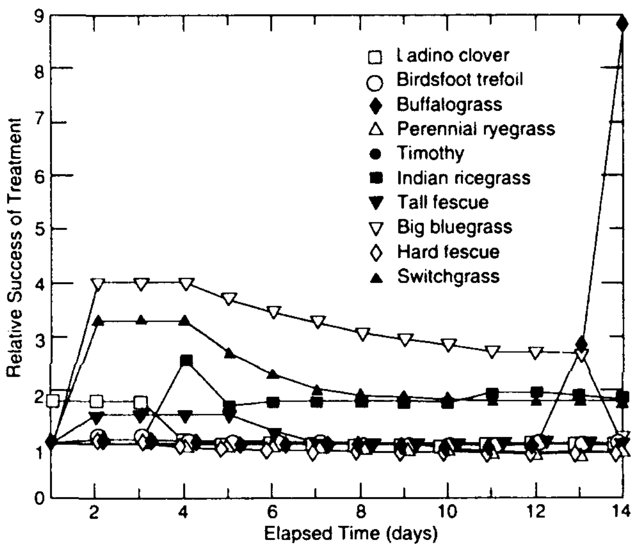
Cold soak—1 day.



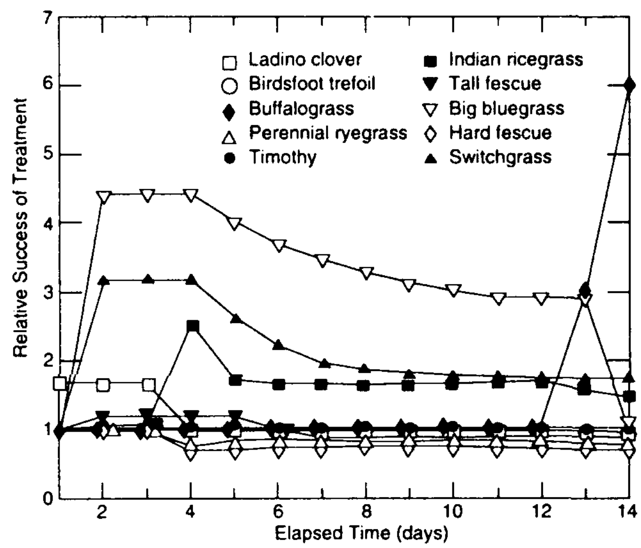
Cold soak—3 days.



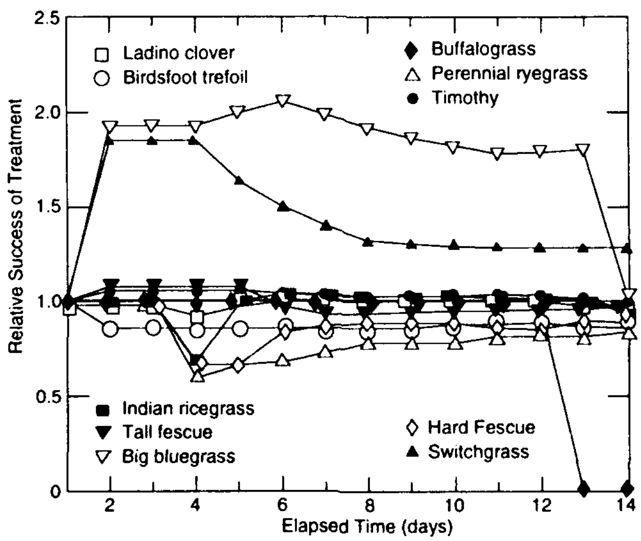
GA_3—200 ppm.



GA_3—2000 ppm.



GA + kinetin.



Kinetin.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1994	

4. TITLE AND SUBTITLE

Effects of Seed Treatments on Germination

5. FUNDING NUMBERS

6. AUTHORS

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755-1290

8. PERFORMING ORGANIZATION REPORT NUMBER

Special Report 94-29

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratory
Champaign, Illinois

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

Available from NTIS, Springfield, Virginia 22161.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The goal of this study was to identify ways to stimulate the germination of seeds of various grasses and legumes of potential value in revegetation of army training grounds or similar damaged lands. Ten treatments (including a control) were used on ten species of plants. Four of the treatments used plant hormones (kinetin and gibberellic acid), and five were environmental, including cold exposure, hot water soaks and cold water soaks. Of these the gibberellic acid treatments yielded the most spectacular results, increasing the germination rate more than three times that of the control in some cases. The environmental treatments were relatively ineffective, although the hot water soaks and the cold exposure often suppressed germination somewhat. Microbial contamination was much reduced by the hot water soak, which may be beneficial in some circumstances.

14. SUBJECT TERMS

Germination, Legumes, Grasses, Revegetation

15. NUMBER OF PAGES

26

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

* U.S. GOVERNMENT PRINTING OFFICE: 1994-600-080/00510